MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

ETM2016 – ANALOG COMMUNICATIONS

(TE)

03 MARCH 2020
02.30 p.m. – 04.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of 10 pages (including 4 appendices) with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Analog modulation is an essential element of analog communication systems.

(i) Write down one advantage of Fourier Series in analog communication.

[2 marks]

(ii) Is Fourier Transform applicable for power signal? Justify your answer.

[4 marks]

(b) Determine if the following signal is an energy or power signal.

$$x(t) = \begin{cases} A\cos 2\pi f_0 t; & for\ -T_0/2 \le t \le T_0/2, \quad where\ T_0 = 1/f_0 \\ 0 & elsewhere \end{cases}$$

[5 marks]

(c) A tone signal s(t) = cos($2\pi f_s t$) is modulated onto a carrier $s_c(t) = A_0\cos(2\pi f_c t)$, with f_c >> f_s. Figure Q1 (a) and Figure Q1 (b) show two modulated signals, s_1(t) and s_2(t) respectively; the dashed lines represent the envelopes of the signals.

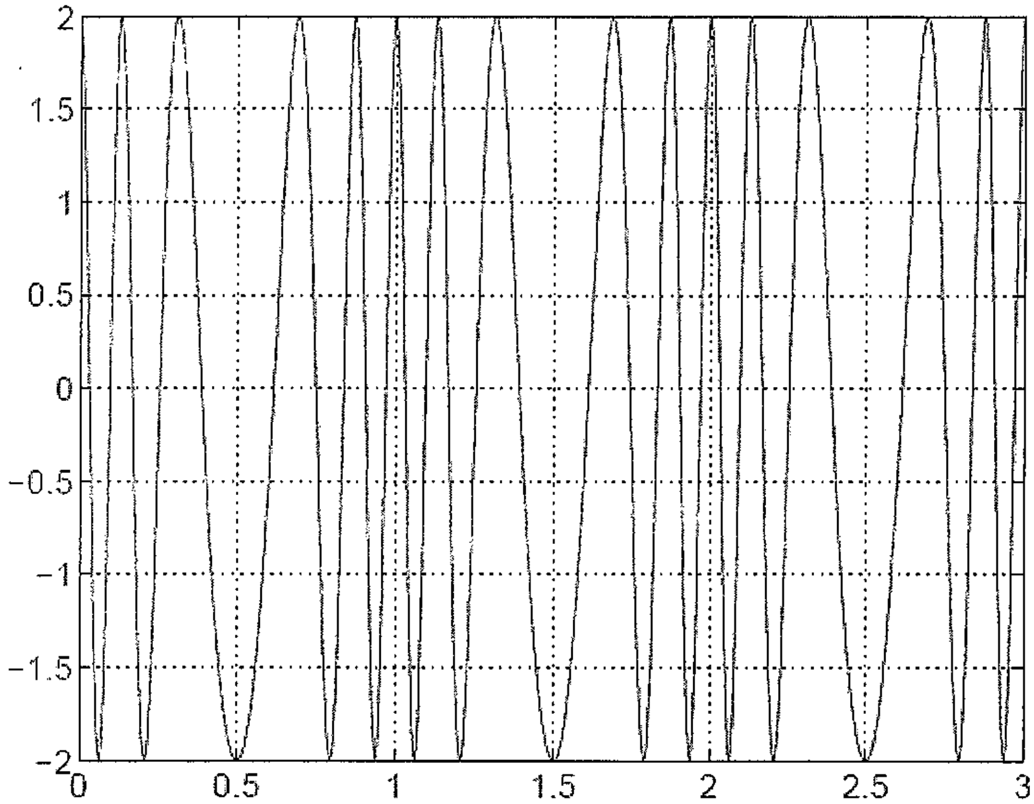

Figure Q1 (a)

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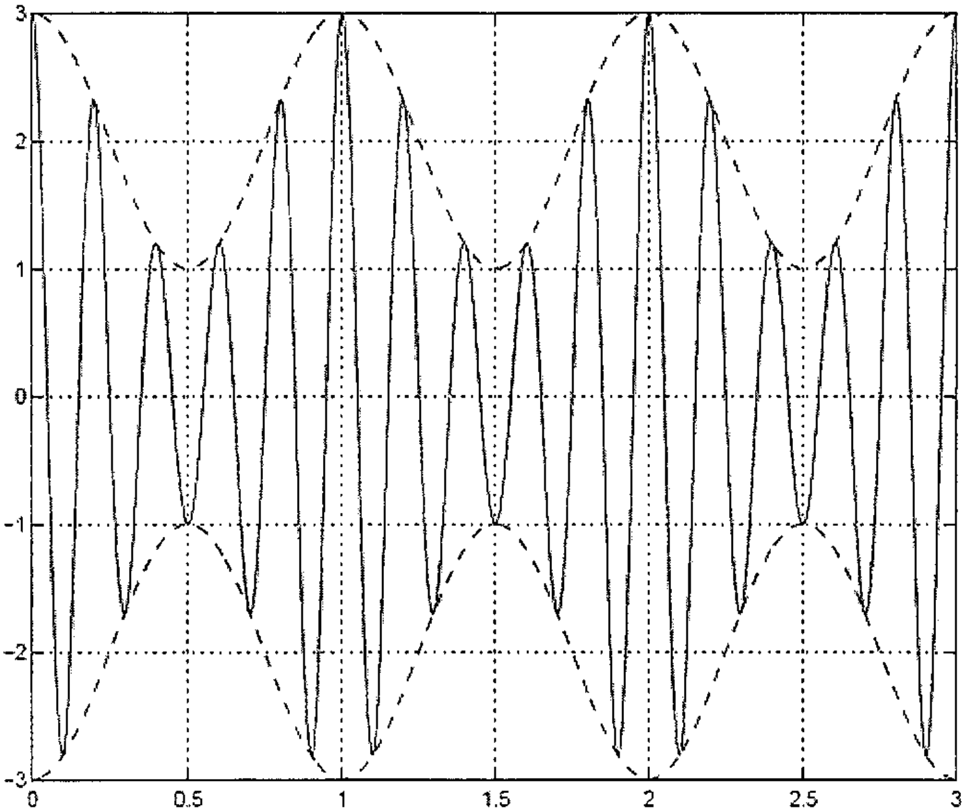

Figure Q1 (b)

(i) Which modulation types were used for $s_1(t)$ and $s_2(t)$?

[2 marks]

(ii) Write down the equation $s_2(t)$ for the modulated signal 2. Give specific values for A_0, f_c, and f_s.

[5 marks]

(iii) Write down the modulation index m for modulated signal 2.

[2 marks]

(iv) Determine the Fourier transform and draw the spectrum of $S_2(f)$. Label the axes.

[5 marks]

Continued...

Question 2

(a) A message signal $f(x)$, as illustrated in Figure Q2.1 below, is used to frequency modulate a carrier signal $s_c(x) = \cos(2\pi 1000kx)$, where $f_c = 2000\ Hz$, $k_f = 500\ Hz/volt$, and x is the time axis in seconds.

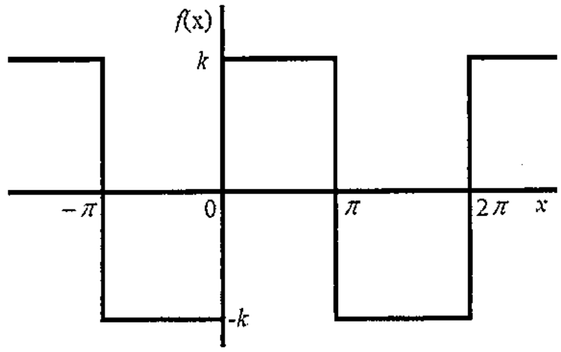

Figure Q2.1

(i) Write the mathematical expression of the frequency modulated signal.
(ii) Determine the instantaneous frequency and phase.
(iii) Sketch the graph of the modulated signal
(iv) If $k = 3$, rewrite the mathematical expression of the modulated signal.

[4+3+3+2 marks]

(b) Consider two signals $s_1(t) = \cos(2\pi f_1 t)$ and $s_2(t) = \cos(2\pi f_2 t)$ shall be transmitted by amplitude modulation. $f_2 = 2f_1 = 20$ kHz, and the modulated signal is of the form

$$s_{BP}(t) = [A + s_1(t) + s_2(t)]\cos(2\pi f_c t); \qquad where \quad f_c = 1000kHz$$

(i) Draw the magnitude spectrum $|S_{BP}(f)|$. Label the axes. [5 marks]

(ii) Assume that the signal $s_{BP}(t)$ has reached the receiver without disturbance. It is down converted to the intermediate frequency f_{ZF}, with $f_{ZF} < f_c$. The mixer in the receiver does that by using the frequency f_M. Figure Q2.2 shows a block diagram of this part of the receiver.

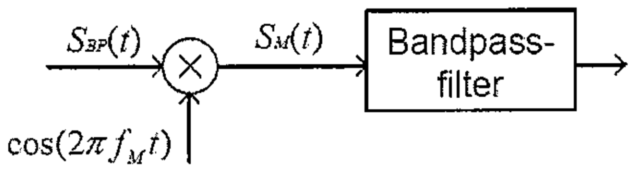

Figure Q2.2

What is the general relation between f_c, f_M and f_{ZF}? Compute all possible values for f_M, which lead to $f_{ZF} = 50$ kHz. [4 marks]

(c) There are various forms of amplitude modulation. Write 4 types of amplitude modulation. [4 marks]

Continued...

Question 3

(a) An analog signal $s(t)$ having a bandwidth of 48 kHz (cut-off frequency f_G = 24kHz) shall be transmitted over a radio link. You can choose between amplitude modulation (AM) and frequency modulation (FM). In case of frequency modulation, the peak frequency deviation is $\Delta F = 5$kHz.

(i) The radio channel allows a bandwidth of 50 kHz. Which modulation scheme can be used (AM, FM or both)? Give reasons. [5 marks]

(ii) Consider the case when the bandwidth of the channel does not matter. Which of the two modulation schemes (AM or FM) is better suited to allow for a high-quality signal transmission that is robust to noise and distance variations between transmitter and receiver? Give reasons. [5 marks]

(b) AM radio station in Kuala Lumpur broadcasts a program with a transmit power of P_T = 200 kW. You receive this radio station with your AM radio receiver in Melaka. The channel attenuation L_A is assumed to be L_A = 30log (30 d/Km) dB; where d stands for the distance between transmitter and receiver (distance Kuala Lumpur –Melaka: 140 km).

(i) The transmit power P_T can be expressed as a level L_{PT} equivalently. Calculate the transmit level L_{PT} in dBm. [2 marks]

(ii) Calculate the channel attenuation L_A. [2 marks]

(iii) Calculate the receive level L_{PR} (in dBm) at your AM-radio in Melaka.

[2 marks]

(c) An antenna has a noise temperature of 50 K. It is connected to a pre-amplifier that has a noise figure of 2 dB and an available gain of 40 dB over an effective bandwidth of 20 MHz.

(i) Find the equivalent noise temperature for the pre-amplifier. [3 marks]

(ii) Find the available noise power of the system. [3 marks]

(iii) Find the available noise power of the system if the gain is reduced by half.

[3 marks]

Continued...

Question 4

(a) A signal $m(t)$ frequency modulated a 100 kHz carrier to produce the following narrowband FM signal:

$$\varphi_{NBFM}(t) = 5\cos\left(2\pi.10^5 t + 0.0050\sin 2\pi.10^4 t\right)$$

Generate (Block diagram design) the wideband FM signal $\varphi_{WBFM}(t)$ with a carrier frequency of 75 MHz and a peak frequency deviation of 75 kHz. Assume that the following are available for the design:

a. Frequency Multipliers of any integer value.
b. A local oscillator whose frequency can be tuned to any value between 50 MHz to 150 MHz.
c. An ideal bandpass filter with tunable center frequency and bandwidth.

Your block diagram design must clearly specify the carrier frequencies and frequency deviations at all logical points, as well as the center frequency and bandwidth of the bandpass filter. Analyse this FM generation method as compared to the direct FM generation method.

[11 marks]

(b) One of the drawbacks of a superheterodyne receiver is the existence of an image frequency. Analyse and explain this undesired input frequency and support your answer with equations.

[6 marks]

(c) A superheterodyne FM receiver operates in the frequency range of 88MHz–108MHz. The intermediate frequency IF and local oscillator frequencies are chosen such that $f_{IF} < f_{LO}$. We require that the image frequency f_{IM} fall outside of the 88MHz–108MHz region.

(i) Determine the minimum required f_{IF} and the range of variations in f_{LO}.
(ii) Examine and analyse the image frequency if $f_{IF} = 0$ Hz.

[6+2 marks]

Continued…

Appendix I

Trigonometric Preliminaries

1. $\sin(n\pi) = 0,\ n = \text{integer}$
2. $\cos(n\pi) = (-1)^n = \begin{cases} 1, & n = even \\ -1, & n = odd \end{cases}$
3. $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$
4. $\cos^2 x = \frac{1}{2}(1 + \cos 2x)$
5. $\sin x \sin y = \frac{1}{2}\left[-\cos(x+y) + \cos(x-y)\right]$
6. $\cos x \cos y = \frac{1}{2}\left[\cos(x+y) + \cos(x-y)\right]$
7. $\sin x \cos y = \frac{1}{2}\left[\sin(x+y) + \sin(x-y)\right]$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta} - e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

$$\int x\cos(ax)dx = \frac{x\sin(ax)}{a} + \frac{\cos(ax)}{a^2}$$

$$\int x\sin(ax)dx = \frac{-x\cos(ax)}{a} + \frac{\sin(ax)}{a^2}$$

Continued...

Appendix II

Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi f t_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\|t\|}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$t^n e^{-at}u(t)$	$\frac{n!}{(a+j2\pi f)^{n+1}}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\mathrm{sinc}(fT)$
$\mathrm{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\mathrm{sinc}^2\left(\frac{fT}{2}\right)$
$W\mathrm{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$

Continued...

Appendix III

Fourier Transform Pairs and Properties

$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$
$\mathrm{sgn}(t)=\begin{cases}1 & t>0\\ -1 & t<0\end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\,\mathrm{sgn}(f)$
$\sum_{i=-\infty}^{\infty}\delta(t-iT_o)$	$\frac{1}{T_o}\sum_{n=-\infty}^{\infty}\delta(f-\frac{n}{T_o})$
$e^{-at}\cos(2\pi f_o t)u(t)$	$\frac{a+j2\pi f}{(a+j2\pi f)^2+(2\pi f_o)^2}$, for $a>0$
$e^{-at}\sin(2\pi f_o t)u(t)$	$\frac{2\pi f_o}{(a+j2\pi f)^2+(2\pi f_o)^2}$, for $a>0$

Let $x(t)\Leftrightarrow X(f)$, $x_1(t)\Leftrightarrow X_1(f)$ and $x_2(t)\Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.

Linearity	$ax_1(t)+bx_2(t)\Leftrightarrow aX_1(f)+bX_2(f)$
Conjugation	$x^*(t)\Leftrightarrow X^*(-f)$
Duality	$X(t)\Leftrightarrow x(-f)$
Scaling ($a\neq 0$)	$x(at)\Leftrightarrow \frac{1}{\lvert a\rvert}X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_o)\Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t}\Leftrightarrow X(f-f_o)$
Modulation	$x(t)\cos(2\pi f_0 t)\Leftrightarrow \frac{1}{2}X(f-f_0)+\frac{1}{2}X(f+f_0)$
Time Differentiation	$\frac{d^n}{dt^n}x(t)\Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t)\Leftrightarrow \frac{d^n}{df^n}X(f)$

Continued...

Appendix IV

Bessel Function Table

n	$\beta = 0$	$\beta = 0.05$	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 5$	$\beta = 7$	$\beta = 8$	$\beta = 10$
0	1.000	0.999	0.998	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178	0.300	0.172	-0.246
1		0.025	0.050	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328	-0.005	0.235	0.043
2			0.001	0.005	0.011	0.031	0.059	0.115	0.353	0.486	0.047	-0.301	-0.113	0.255
3					0.001	0.003	0.007	0.020	0.129	0.309	0.365	-0.168	-0.291	0.058
4							0.001	0.002	0.034	0.132	0.391	0.158	-0.105	-0.220
5									0.007	0.043	0.261	0.348	0.186	-0.234
6									0.001	0.011	0.131	0.339	0.338	-0.014
7										0.003	0.053	0.234	0.321	0.217
8											0.018	0.128	0.223	0.318
9											0.006	0.059	0.126	0.292
10											0.001	0.024	0.061	0.207
11												0.008	0.026	0.123
12												0.003	0.010	0.063
13												0.001	0.003	0.029
14													0.001	0.012
15														0.005
16														0.002
17														0.001

	N		N		N		N
$\beta = 0.05$	1	$\beta = 0.7$	4	$\beta = 5$	10	$\beta = 20$	28
$\beta = 0.1$	2	$\beta = 0.8$	4	$\beta = 6$	12	$\beta = 25$	34
$\beta = 0.2$	2	$\beta = 0.9$	4	$\beta = 7$	13	$\beta = 30$	39
$\beta = 0.3$	3	$\beta = 1$	4	$\beta = 8$	14	$\beta = 35$	45
$\beta = 0.4$	3	$\beta = 2$	6	$\beta = 9$	15	$\beta = 40$	50
$\beta = 0.5$	3	$\beta = 3$	7	$\beta = 10$	17	$\beta = 45$	55
$\beta = 0.6$	3	$\beta = 4$	9	$\beta = 15$	22	$\beta = 50$	61

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